Sensor-aided Milling with a Surgical Robot System

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Project 10: Real Time Motion Reflexes for Robotic Hip Surgery

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Project Overview

- Utilize torque sensor data in KUKA robot arm to provide realtime feedback and improve robotic hip surgery
  - Force-controlled velocity
  - Null-space compliance

Sensor-aided Milling with a Surgical Robot System

D. Engel, J. Raczkowsky, H. Wörn, “Sensor-aided Milling with a Surgical Robot System”, CARS 2002, H.U. Lemke et al. (eds.), 2002.

- Focuses on tool deflection, errors caused, solutions proposed

Overview of Paper

- Robotic craniofacial surgery uses a robot arm that cuts bone
- Tool deflection can occur up to 1.5 mm
- Calibration approach considering this tool deflection
- Registration and intervention compensate for deflection
- Discrete controlling algorithm

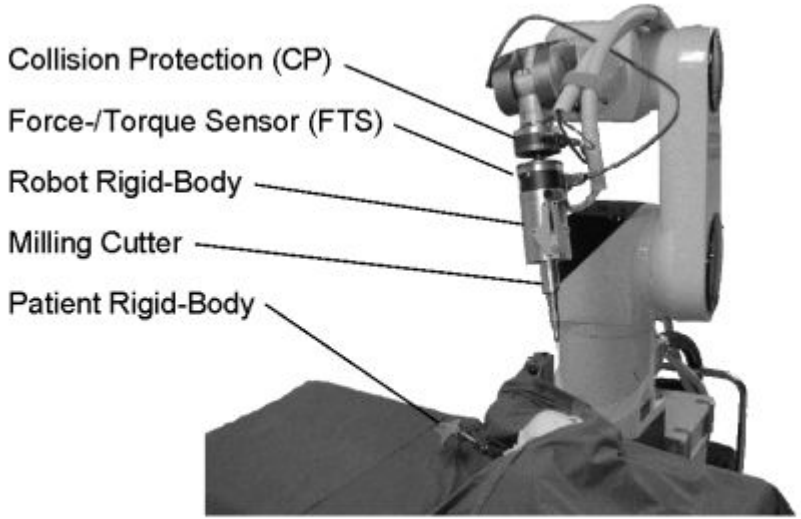
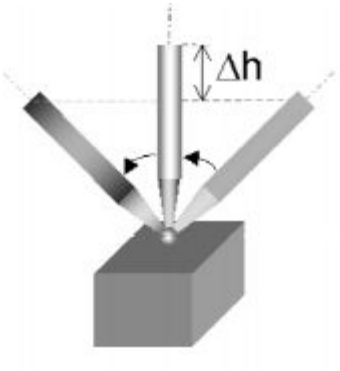


Fig. 1: RobaCKa system set-up, robot and sensors

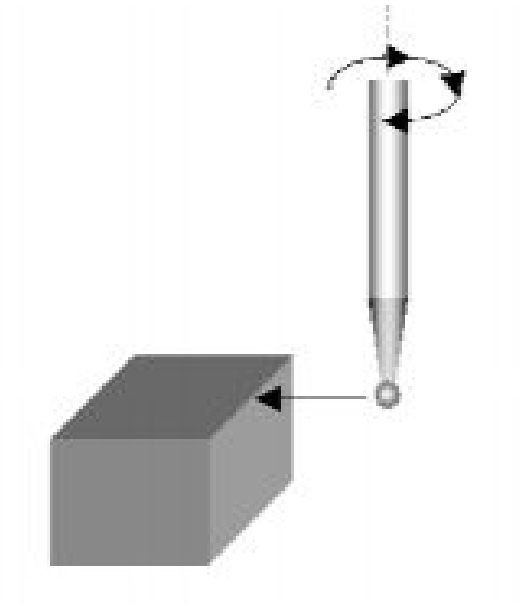
Calibration: Tool Dimension



$$l = (2+\sqrt{2})\Delta h\,,\quad \Delta h = h_{90^\circ} - 0.5\left(h_{-45^\circ} + h_{+45^\circ}\right).$$

Calibration: x- and y-axis Offset

- Positive x-axis makes contact with left side of calibrating body
- Detach and rotate 90° about z-axis
- Make contact for positive/negative x-/y-axis



Calibration: Tool Deflection

- Deflection in x,y direction denoted d_x and d_y
- d_z ignored because d_x,d_y << L

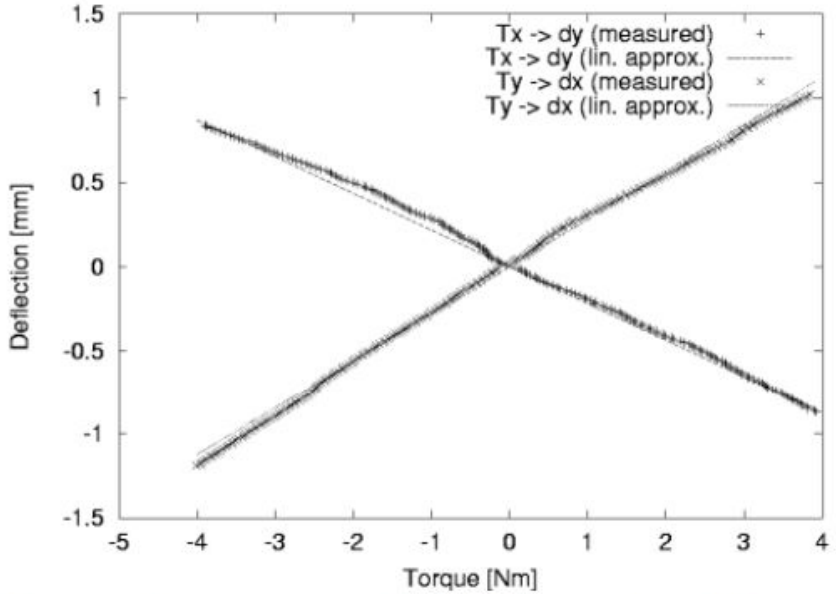


Fig. 3: Correlation of affecting torque and tool deflection. The correlation can be linear approximated by $d_x = c_y T_y$ and $d_y = c_x T_x$ ($c_{x,y}$: constant factors)

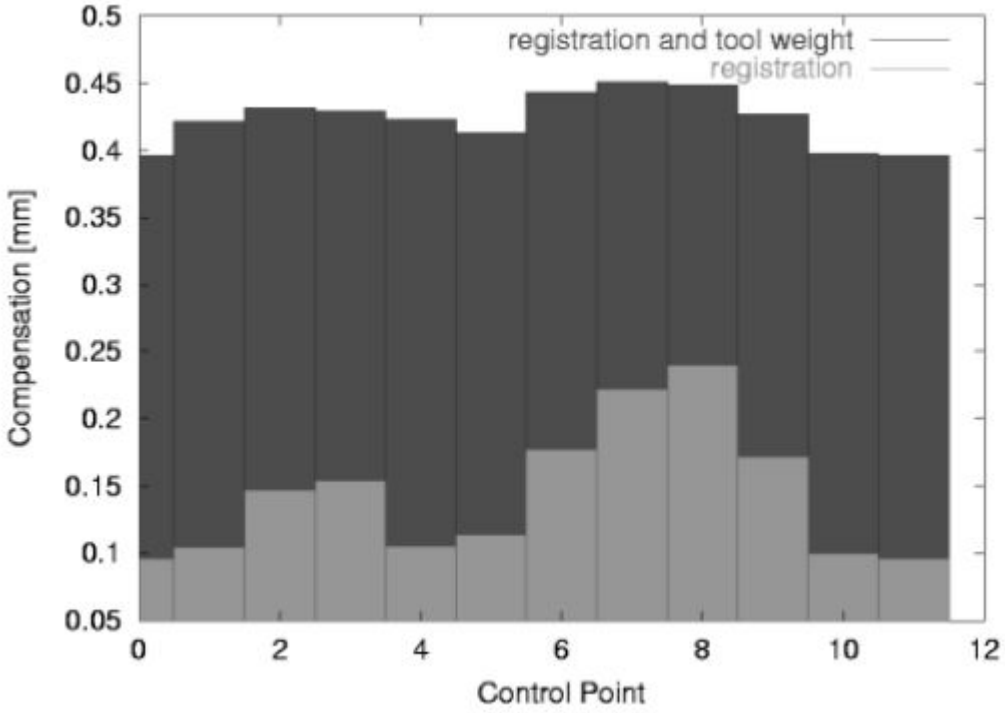
Registration

- Four screws implanted into patient's head
- Guide robot tool tip to fiducial landmark points (ball
- User force must exceed required force to be safe against tremor and hitches
- Bending stress possible when tool tip placed in screw cone
- Offset vector **d** = (d_x, d_y, 0) corresponding to torques added to measured position

Execution of Cut Trajectory

- Can calculate tool deflection from weight of tool before actual cutting starts
- During cutting, the speed is controlled by discrete controlling algorithm
  - Torque less than lower limit, increase speed
  - Torque within limits, keep speed
  - Torque greater than upper limit, decrease speed to minimum value
- Tool acceleration and cutting depth also affects tool deflection
- Break up deep cuts into several steps with different depths

Compensation for Registration and Tool Weight



Paper Evaluation

- Clear, detailed explanations
- Not too technical
- Could use more data for results of tool deflection correction methods
- Could use data for discrete controlling algorithm

Relevance to Our Project

- Tool deflection is a problem that could affect any robotic surgery involving bone cutting
- Currently working on providing real-time feedback to correct for errors

Questions?